

(19)



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Office européen des brevets



(11)

EP 0 440 166 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:
28.07.1999 Bulletin 1999/30

(51) Int Cl. 6: G06T 5/20, H04N 1/407

(21) Application number: 91101148.4

(22) Date of filing: 29.01.1991

(54) Method for compressing dynamic ranges of images

Verfahren zum Komprimieren von Bild dynamikbereichen

Méthode de compression de gammes dynamiques d'images

(84) Designated Contracting States:
DE FR NL

(30) Priority: 29.01.1990 JP 1820690

(43) Date of publication of application:
07.08.1991 Bulletin 1991/32

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- PROC. OF THE SPIE - THE INTERNATIONAL SOCIETY FOR OPTICAL ENGINEERING vol. 626, 1986 pages 259 - 267 MITCHELL CR ET AL. 'Digital image processing in chest radiography'
- PROC. OF THE SPIE - THE INTERNATIONAL SOCIETY FOR OPTICAL ENGINEERING vol. 419, 1983 pages 282 - 288 HASEGAWA BH ET AL. 'Selective exposure radiography using digitally-formed x-ray beam attenuators'
- PROC. OF THE SOCIETY OF PHOTO-OPTICAL INSTRUMENTATION ENGINEERS vol. 238, 1980 pages 91 - 102 CHUN MOO L 'Forward looking infrared (FLIR) image enhancement for automatic target cuer system'

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Description**BACKGROUND OF THE INVENTION**5 **Field of the Invention**

[0001] This invention relates to a method for compressing a dynamic range of an image, with which an original image signal representing an original image is processed, and a processed image signal representing an image having a narrower dynamic range than the original image is thereby generated.

10 **Description of the prior Art**

[0002] Techniques for reading out a recorded image in order to obtain an image signal, carrying out appropriate image processing on the image signal, and then reproducing a visible image by use of the processed image signal have heretofore been known in various fields. For example, as disclosed in Japanese Patent Publication No. 61(1986)-5193, an X-ray image is recorded on an X-ray film having a small gamma value chosen according to the type of image processing to be carried out, the X-ray image is read out from the X-ray film and converted into an electric signal (image signal), and the image signal is processed and then used for reproducing the X-ray image as a visible image on a copy photograph, or the like. In this manner, a visible image having good image quality with high contrast, high sharpness, high graininess, or the like can be reproduced.

[0003] Also, when certain kinds of phosphors are exposed to radiation such as X-rays, α -rays, β -rays, γ -rays, cathode rays or ultraviolet rays, they store part of the energy of the radiation. Then, when the phosphor which has been exposed to the radiation is exposed to stimulating rays such as visible light, light is emitted by the phosphor in proportion to the amount of energy stored thereon during its exposure to the radiation. A phosphor exhibiting such properties is referred to as a stimulable phosphor.

[0004] As disclosed in U.S. Patent Nos. 4,258,264, 4,276,473, 4,315,318, 4,387,428 (corresponding to the preamble of claim 1), and Japanese Unexamined Patent Publication No. 56(1981)-11395, it has been proposed to use stimulable phosphors in radiation image recording and reproducing systems. Specifically, a sheet provided with a layer of the stimulable phosphor (hereinafter referred to as a stimulable phosphor sheet) is first exposed to radiation which has passed through an object, such as the human body. A radiation image of the object is thereby stored on the stimulable phosphor sheet. The stimulable phosphor sheet is then scanned with stimulating rays, such as a laser beam, which cause it to emit light in proportion to the amount of energy stored thereon during its exposure to the radiation. The light emitted by the stimulable phosphor sheet, upon stimulation thereof, is photoelectrically detected and converted into an electric image signal. The image signal is then used during the reproduction of the radiation image of the object as a visible image on a recording material such as photographic film, on a display device such as a cathode ray tube (CRT) display device, or the like.

[0005] Radiation image recording and reproducing systems which use stimulable phosphor sheets are advantageous over conventional radiography using silver halide photographic materials, in that images can be recorded even when the energy intensity of the radiation to which the stimulable phosphor sheet is exposed varies over a wide range. More specifically, since the amount of light which the stimulable phosphor sheet emits when being stimulated varies over a wide range and is proportional to the amount of energy stored thereon during its exposure to the radiation, it is possible to obtain an image having a desirable density regardless of the energy intensity of the radiation to which the stimulable phosphor sheet was exposed. In order to obtain the desired image density, an appropriate read-out gain is set when the emitted light is being detected and converted into an electric signal to be used in the reproduction of a visible image on a recording material, such as photographic film, or on a display device, such as a CRT display device.

[0006] In the image recording and reproducing systems, with which image signals are generated and visible images are reproduced from the image signals, it often occurs that portions of an image, which are to be used and therefore are required to have an appropriate image density in the reproduced image, have image density levels ranging widely from a low density to a high density. Also, it often occurs that what portions of an image having which range of image density are to be used and therefore are required to have an appropriate image density in the reproduced image. In such cases, the image signal representing the original image is processed such that the high-density parts of the original image may have an appropriate level of image density in the reproduced image. Also, the image signal representing the original image is processed such that the low-density parts of the original image may have an appropriate level of image density in the reproduced image. Thereafter, both the images reproduced from the image signals, which have thus been processed in different ways, are displayed side by side on a single display device.

[0007] However, if a plurality of images are displayed side by side on a single display device, the problems will occur in that the images inevitably become small in size and therefore hard to observe.

[0008] In order that parts of an image covering as wide a range of image density as possible can be used, the level

of contrast of the parts of the image having a high or low image density or the level of contrast of the whole image has heretofore been rendered low such that the difference between the highest image density and the lowest image density may become small, i.e. such that the dynamic range of the image may become narrow.

[0009] Further, image processing techniques are known from the following publications. In an article in Proceedings of the Society of Photo-optical Instrumentation Engineers, vol. 238, 1980, pages 91 to 102, by Chun Moo Lo, entitled "Forward Looking Infrared (FLIR) Image Enhancement for Automatic Target Cuer System" an image processing method is described which tries to solve the need for a local area contrast enhancement to compress the global scene dynamic range presented to the display by preserving local area contrast.

[0010] In an article in Proceedings of the SPIE - The International Society for Optical Engineering, vol. 626, 1986, pages 259 to 267, by Mitchell CR et al, entitled "Digital Image Processing in Chest Radiography" an image processing algorithm is suggested for performing unsharp masking for reduction of large area contrast produced by wide exposure ranges.

[0011] However, if the level of contrast is rendered low, the problems will occur in that details of the image information in the image region, at which the level of contrast has been lowered, becomes hard to observe.

[0012] How the problems described above occur will be described hereinbelow.

[0013] Figure 8 is a graph showing an example of how the values of the image signal components of an original image signal S_{org} are distributed, which image signal components represent picture elements located along a certain direction (the direction indicated by the arrow x) on an original image. As a whole, the values of the image signal components of the original image signal S_{org} are distributed in a step-like pattern along the direction indicated by the arrow x (i.e. the image density of the original image changes step-wise along the direction indicated by the arrow x). Each step part of the distribution of the image density includes a fine change having a comparatively high spatial frequency.

[0014] Figure 9A is a graph showing an example of characteristics with which an original image signal S_{org} representing an image is transformed into an image signal $S_{org'}$ such that the dynamic range of the image may be compressed by lowering the level of contrast of part having a high image density. Figure 9B is a graph showing how the values of the image signal components of the image signal $S_{org'}$ resulting from the transformation with the characteristics illustrated in Figure 9A are distributed, which image signal components represent picture elements located along the direction indicated by the arrow x on the image.

[0015] In this example, the original image signal S_{org} having values shown in Figure 8 is transformed into the image signal $S_{org'}$ having values lying on the line A shown in Figure 9A. As a result, as illustrated in Figure 9B, the level of image density in the part having a high image density become low. Also, the level of contrast of the fine image structures represented by the fine change in each step part of the distribution of the image density, which step part falls within the high density region, becomes low. Therefore, the fine image structures having a high image density, which image structures are to be used and therefore are required to have good image quality in the reproduced image, become very hard to observe.

[0016] Figure 10A is a graph showing an example of characteristics with which an original image signal S_{org} representing an image is transformed into an image signal $S_{org'}$ such that the dynamic range of the image may be compressed by lowering the level of contrast of part having a low image density. Figure 10B is a graph showing how the values of the image signal components of the image signal $S_{org'}$ resulting from the transformation with the characteristics illustrated in Figure 10A are distributed, which image signal components represent picture elements located along the direction indicated by the arrow x on the image.

[0017] In this example, the original image signal S_{org} having values shown in Figure 8 is transformed into the image signal $S_{org'}$ having values lying on the line B shown in Figure 10A. In such cases, as illustrated in Figure 10B, the fine image structures having a low image density become very hard to observe.

45 SUMMARY OF THE INVENTION

[0018] The primary object of the present invention is to provide a method for compressing a dynamic range of an image, with which the range of image density of an image is compressed such that parts of the image covering a wide range of image density can be used and may have good image quality in the reproduced visible image, and the image quality of fine image structures at each of parts having various levels of image density may be kept good.

[0019] Another object of the present invention is to provide a method for compressing a dynamic range of an image, wherein an image signal representing the image is processed such that no artificial contour occurs in the visible image reproduced from the processed image signal. The present invention is set out in claim 1.

[0020] The value of $f(S_{us})$ need not necessarily change for every value of the unsharp mask signal S_{us} , and may not change for a certain range of values of the unsharp mask signal S_{us} .

[0021] With the method for compressing a dynamic range of an image in accordance with the present invention, the unsharp mask signal S_{us} is generated by emphasizing the low spatial frequency components of the original image

signal S_{org} . Thereafter, by using the function $f(S_{us})$, the value of which decreases monotonously as the value of the unsharp mask signal S_{us} increases, values of the processed image signal S_{proc} are calculated by compressing the dynamic range of the image with the formula

5 $S_{proc} = S_{org} + f(S_{us})$ (3)

10 Therefore, the dynamic range of the whole image is compressed. Also, the contrast of fine image structures, which have many comparatively high spatial frequency components and are located at each of parts having various levels of image density, can be kept high. Accordingly, parts of the image covering a wide range of image density can be used and may have good image quality in the reproduced visible image.

15 [0022] Also, with the method for compressing a dynamic range of an image in accordance with the present invention, only by modifying the characteristics of the function $f(S_{us})$, the dynamic range of parts of the image, which parts have low levels of image density, and the dynamic range of parts of the image, which have high levels of image density can be compressed. The process for compressing the dynamic range of parts of the image, which parts have low levels of image density, is advantageous when, for example, a mediastinum region is to be used in an X-ray image of the chest. The process for compressing the dynamic range of parts of the image, which parts have high levels of image density, is advantageous when, for example, a skin edge region is to be used in an X-ray image of bones of limbs.

20 [0023] If a function $f(S_{us})$ with a continuous differential coefficient is utilized, no artificial contour occurs in the image represented by the processed image signal S_{proc} , and an image having good image quality can be obtained.

[0024] A technique for compressing a dynamic range of an X-ray image of the chest of a human body is disclosed, for example, in "Journal of Japanese Society of Radiological Technology", Vol. 45, No. 8, p. 1030, August 1989, Mitsuhiro Anan, et al. The disclosed technique comprises the steps of:

25 1) calculating the values of an unsharp mask signal S_{us} ,
 2) doubling the values of the unsharp mask signal S_{us} , the resulting value being clipped at the maximum value (1023) in cases where the resulting value exceeds the maximum value (1023),

30
$$a = \begin{cases} 2 \times S_{us} & (2 \times S_{us} < 1023) \\ 1023 & (2 \times S_{us} \geq 1023) \end{cases} \dots (4)$$

35 3) calculating the values of an image signal representing a reversal image with the formula

$b = 1023 - a$

40 and
 4) adding the products of the values of the image signal representing the reversal image and a coefficient, α , to the values of the image signal representing the original image with the formula

$c = S_{org} + \alpha \cdot b \quad (\alpha = 0.3)$ (5)

45 The disclosed technique has the effects of compressing the dynamic range of an image and keeping the contrast of fine image structures, which are present in each of parts having various levels of image density, high.

50 [0025] However, with the disclosed technique, only the dynamic range of parts of the image, which parts have low levels of image density, can be compressed. With the disclosed technique, the dynamic range of parts of the image, which parts have high levels of image density, cannot be compressed. Therefore, the disclosed technique has the drawback in that it is not suitable for images of bones of limbs, or the like. On the other hand, with the method for compressing a dynamic range of an image in accordance with the present invention, the dynamic range of parts of the image, which parts have high levels of image density, can also be compressed efficiently. Also, the disclosed technique has the risk that an artificial contour may occur in a visible image reproduced from the processed image signal and adversely affects the image quality of the visible image. On the other hand, the method for compressing a dynamic range of an image in accordance with the present invention has no such risk. As described above, the method for compressing a dynamic range of an image in accordance with the present invention eliminates the drawbacks of the

disclosed technique. Also, the method for compressing a dynamic range of an image in accordance with the present invention is composed of simpler steps than the disclosed technique. Additionally, the method for compressing a dynamic range of an image in accordance with the present invention is advantageous in that, for example, the compressibility can be set arbitrarily.

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BRIEF DESCRIPTION OF THE DRAWINGS

[0026] Figure 1 is an explanatory view showing picture elements in an original image and image signal components of an original image signal Sorg, which represent the picture elements,

10 [0027] Figure 2 is a graph showing an example of a monotonously decreasing function, in which the value of an unsharp mask signal Sus serves as a variable and which is employed in an embodiment of the method for compressing a dynamic range of an image in accordance with the present invention,

[0028] Figure 3 is a graph showing how the values of the image signal components of a processed image signal Sproc are distributed, the processed image signal Sproc being obtained by processing an original image signal Sorg made up of a series of image signal components, which represent picture elements located along the direction indicated by the arrow x on an original image, and the values of which are distributed as shown in Figure 8,

15 [0029] Figure 4 is a graph showing another example of a monotonously decreasing function, in which the value of an unsharp mask signal Sus serves as a variable and which is employed in another embodiment of the method for compressing a dynamic range of an image in accordance with the present invention,

20 [0030] Figure 5 is a graph showing how the values of the image signal components of a processed image signal Sproc are distributed, the processed image signal Sproc being obtained when the function f(Sus) illustrated in Figure 4 is employed in the course of processing an original image signal Sorg made up of a series of image signal components, the values of which are distributed as shown in Figure 8,

[0031] Figure 6 is a schematic view showing an example of an X-ray image recording apparatus,

25 [0032] Figure 7 is a perspective view showing an example of an X-ray image read-out apparatus,

[0033] Figure 8 is a graph showing an example of how the values of the image signal components of an original image signal Sorg are distributed, which image signal components represent picture elements located along a certain direction (the direction indicated by the arrow x) on an original image,

30 [0034] Figure 9A is a graph showing an example of characteristics with which an original image signal Sorg representing an image is transformed into an image signal Sorg' such that the dynamic range of the image may be compressed by lowering the level of contrast of part having a high image density,

[0035] Figure 9B is a graph showing how the values of the image signal components of the image signal Sorg' resulting from the transformation with the characteristics illustrated in Figure 9A are distributed, which image signal components represent picture elements located along the direction indicated by the arrow x on the image,

35 [0036] Figure 10A is a graph showing an example of characteristics with which an original image signal Sorg representing an image is transformed into an image signal Sorg' such that the dynamic range of the image may be compressed by lowering the level of contrast of part having a low image density, and

[0037] Figure 10B is a graph showing how the values of the image signal components of the image signal Sorg' resulting from the transformation with the characteristics illustrated in Figure 10A are distributed, which image signal components represent picture elements located along the direction indicated by the arrow x on the image.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

40 [0038] The present invention will hereinbelow be described in further detail with reference to the accompanying drawings.

[0039] In the embodiments described below, an X-ray image is stored on a stimulable phosphor sheet.

[0040] Figure 6 is a schematic view showing an example of an X-ray image recording apparatus.

45 [0041] With reference to Figure 6, X-rays 12 are produced by an X-ray source 11 of an X-ray image recording apparatus and irradiated to an object 13. The X-rays, which have passed through the object 13, impinge upon a stimulable phosphor sheet 14. In this manner, an X-ray image of the object 13 is stored on the stimulable phosphor sheet 14.

[0042] Figure 7 is a perspective view showing an example of an X-ray image read-out apparatus.

[0043] With reference to Figure 7, a stimulable phosphor sheet 14, on which an X-ray image has been stored in the X-ray image recording apparatus shown in Figure 6, is placed at a predetermined position in a read-out means 20.

50 [0044] The stimulable phosphor sheet 14 is then conveyed in a sub-scanning direction indicated by the arrow Y by an endless belt 22, which is operated by a motor 21. A laser beam 24, which serves as stimulating rays, is produced by a laser beam source 23, and is reflected and deflected by a rotating polygon mirror 26 which is quickly rotated by a motor 25 in the direction indicated by the arrow. The laser beam 24 then passes through a converging lens 27 constituted of an $f\theta$ lens or the like. The direction of the optical path of the laser beam 24 is then changed by a mirror

28, and the laser beam 24 impinges upon the stimulable phosphor sheet 14 and scans it in a main scanning direction indicated by the arrow X, which direction is approximately normal to the sub-scanning direction indicated by the arrow Y. When the stimulable phosphor sheet 14 is exposed to the laser beam 24, the exposed portion of the stimulable phosphor sheet 14 emits light 29 in an amount proportional to the amount of energy stored thereon during its exposure to the X-rays. The emitted light 29 is guided by a light guide member 30 and photoelectrically detected by a photomultiplier 31. The light guide member 30 is made from a light guiding material such as an acrylic plate and has a linear light input face 30a, positioned so that it extends along the main scanning line on the stimulable phosphor sheet 14, and a ring-shaped light output face 30b, positioned so that it is in close contact with a light receiving face of the photomultiplier 31. The emitted light 29, which has entered the light guide member 30 at its light input face 30a, is guided through repeated total reflection inside of the light guide member 30, emanates from the light output face 30b, and is received by the photomultiplier 31. In this manner, the amount of the emitted light 29, which amount represents the X-ray image, is converted into an electric signal by the photomultiplier 31.

[0045] An analog output signal S0 generated by the photomultiplier 31 is logarithmically amplified by a logarithmic amplifier 32, and digitized by an A/D converter 33. In this manner, an original image signal Sorg is obtained. The original image signal Sorg is then fed into an image processing and reproducing means 40. The image processing and reproducing means 40 is constituted of a CRT display device 41 which reproduces and displays a visible image, a main body 42 in which a CPU, an internal memory, an interface, or the like, are incorporated, a floppy disk drive unit 43 which operates a floppy disk, and a keyboard 44 from which necessary information is fed into the X-ray image read-out apparatus.

[0046] After the original image signal Sorg representing the original X-ray image of the object 13 is fed into the image processing and reproducing means 40, the dynamic range of the image is compressed by transforming the original image signal Sorg in the manner described below.

[0047] Figure 1 is an explanatory view showing picture elements in an original image and image signal components of an original image signal Sorg, which represent the picture elements. In Figure 1, dots represent the picture elements, and the symbols such as S_{ij} represent the image signal components of the original image signal Sorg which represent the corresponding picture elements. The value of an unsharp mask signal S_{us}^{ij} for the picture element, which is located in the middle of the region surrounded by the chained line, is calculated with the formula

$$30 \quad S_{us}^{ij} = \frac{\sum_{k=-m}^m \sum_{l=-n}^n S_{i+k, j+l}}{(2m+1) \cdot (2n+1)}$$

35

By carrying out the calculation for every picture element, an unsharp mask signal Sus for the whole image is generated. The values of m and n are determined arbitrarily in accordance with the intervals, with which the original image signal Sorg is sampled, the characteristics of the original X-ray image, or the like.

[0048] Figure 2 is a graph showing an example of a monotonously decreasing function, in which the value of an unsharp mask signal Sus serves as a variable and which is employed in an embodiment of the method for compressing a dynamic range of an image in accordance with the present invention.

[0049] The maximum value of the unsharp mask signal Sus is 1,023. When the value of the unsharp mask signal Sus falls within the range of 0 to d, the value of the function f(Sus) is zero. When the value of the unsharp mask signal Sus is larger than d, the function f(Sus) takes values lying on the inclined straight line. For each picture element (i,j), a calculation using the function f(Sus) is carried out with the formula

$$S_{proc}^{ij} = S_{ij} + f(S_{us}^{ij})$$

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In this manner, a processed image signal Sproc corresponding to all of the picture elements in the image is generated.

[0050] Figure 3 is a graph showing how the values of the image signal components of a processed image signal Sproc are distributed, the processed image signal Sproc being obtained by processing an original image signal Sorg made up of a series of image signal components, which represent picture elements located along the direction indicated by the arrow x on an original image, and the values of which are distributed as shown in Figure 8.

[0051] As illustrated in Figure 3, the dynamic range of the parts of the image, which are associated with large values of the unsharp mask signal Sus, i.e. which have high levels of mean image density, is compressed. Also, the contrast of fine image structures, which have many comparatively high spatial frequency components and are located at each

of said parts, is kept at the same level as the original contrast. Therefore, when a visible image is reproduced from the processed image signal Sproc and displayed on the CRT display device 41, a visible image is obtained wherein the levels of image density of the parts, which originally had a high image density, are lower than before, and wherein the contrast of the fine image structures in each of said parts is kept high. In cases where, as illustrated in Figure 3, the image density changes step-wise, overshooting or undershooting occurs in the processed image signal Sproc. However, practically, images have no such sharp stepwise changes in image density. Therefore, the problem with regard to overshooting or undershooting need not be taken into consideration.

[0052] Figure 4 is a graph showing another example of a monotonously decreasing function, in which the value of an unsharp mask signal Sus serves as a variable and which is employed in another embodiment of the method for compressing a dynamic range of an image in accordance with the present invention. When the unsharp mask signal Sus takes small values, the value of the function $f(Sus)$ changes. When the unsharp mask signal Sus takes values higher than the level, e , the value of the function $f(Sus)$ is zero.

[0053] Figure 5 is a graph showing how the values of the image signal components of a processed image signal Sproc are distributed, the processed image signal Sproc being obtained when the function $f(Sus)$ illustrated in Figure 4 is employed in the course of processing an original image signal Sorg made up of a series of image signal components, the values of which are distributed as shown in Figure 8.

[0054] As illustrated in Figure 5, the dynamic range of the parts of the image, which have low levels of image density, is compressed. Also, the contrast of fine image structures, which are located at each of said parts, is kept at the same level as the original contrast. Therefore, when a visible image is reproduced from the processed image signal Sproc and displayed on the CRT display device 41, a visible image is obtained wherein the levels of image density of the parts, which originally had a low image density, are higher than before, and wherein the contrast of the fine image structures in each of said parts is kept high.

[0055] As shown in Figure 4, the line representing the function $f(Sus)$ is not folded sharply at the point, e , but the differential coefficient of the function $f(Sus)$ is continuous. In cases where a function $f(Sus)$ is used, which has characteristics such that the line representing it folds sharply at the point, e , even if no particular contour is present in the original image, an artificial contour will occur at the part having the image density corresponding to the point, e , in the visible image reproduced from the processed image signal Sproc. In this embodiment, the function $f(Sus)$ is employed which has characteristics such that the differential coefficient is continuous, no artificial contour occurs in the reproduced visible image.

[0056] In the embodiments described above, an X-ray image is read out from a stimulable phosphor sheet, and an image signal is thereby generated. The method for compressing a dynamic range of an image in accordance with the present invention is broadly applicable when image signals are detected from various kinds of recording media, on which images have been recorded, e.g. when an X-ray image is read out from X-ray film.

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Claims

1. A method for compressing a dynamic range of an image, with which an original image signal Sorg representing an original image is processed, and a processed image signal Sproc representing an image having a narrower dynamic range than the original image is thereby generated,
the method for compressing a dynamic range of an image comprising the steps of:

i) calculating the value of an unsharp mask signal Sus corresponding to each of picture elements in said original image by averaging the values of image signal components of said original image signal Sorg, which image signal components represent the picture elements belonging to a predetermined region surrounding each said picture element, **characterized by**

ii) calculating the values of said processed image signal Sproc with the formula

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$$Sproc = Sorg + f(Sus)$$

where $f(Sus)$ represents a function, the value of which decreases monotonously as the value of said unsharp mask signal Sus increases.

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2. A method as defined in Claim 1 wherein said original image is a radiation image.
3. A method as defined in Claim 2 wherein said radiation image has been stored on a stimulable phosphor sheet.

4. A method as defined in Claim 3 wherein an image signal, which represents said radiation image and serves as said original image signal Sorg, is detected by exposing said stimulable phosphor sheet to stimulating rays, which cause said stimulable phosphor sheet to emit light in proportion to the amount of energy stored thereon during its exposure to radiation, and photoelectrically detecting the emitted light.

5. A method as defined in Claim 4 wherein said stimulating rays are a laser beam.

6. A method as defined in Claim 1 wherein said original image is an X-ray image which has been recorded on photographic film.

10. 7. A method as defined in claim 1, where the differential coefficient of the function $f(S_{us})$ is continuous.

8. A method as defined in Claim 7 wherein said original image is a radiation image.

15. 9. A method as defined in Claim 8 wherein said radiation image has been stored on a stimulable phosphor sheet.

10. A method as defined in Claim 9 wherein an image signal, which represents said radiation image and serves as said original image signal Sorg, is detected by exposing said stimulable phosphor sheet to stimulating rays, which cause said stimulable phosphor sheet to emit light in proportion to the amount of energy stored thereon during its exposure to radiation, and photoelectrically detecting the emitted light.

20. 11. A method as defined in Claim 10 wherein said stimulating rays are a laser beam.

12. A method as defined in Claim 7 wherein said original image is an X-ray image which has been recorded on photographic film.

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Patentansprüche

30. 1. Verfahren zum Komprimieren eines Dynamikbereichs eines Bildes, mit dem ein ein Originalbild repräsentierendes Originalbildsignal S_{org} verarbeitet wird, und wobei ein verarbeitetes Bildsignal S_{proc} erzeugt wird, das ein Bild repräsentiert, welches einen engeren Dynamikbereich als das Originalbild hat, wobei das Verfahren zum Komprimieren eines Dynamikbereichs eines Bildes die Schritte umfaßt:

35. i) Berechnen des Wertes eines Unschärtemaskensignals S_{us} , welches jeweils Bildelementen in dem Originalbild entspricht, durch Mitteln der Werte von Bildsignalkomponenten des Originalbildsignals S_{org} , wobei die Bildsignalkomponenten die Bildelemente repräsentieren, die zu einem vorbestimmten, jedes Bildelement umgebenden Bereich gehören, **dadurch gekennzeichnet**, daß

40. ii) die Werte des verarbeiteten Bildsignals S_{proc} mit der Formel

$$S_{proc} = S_{org} + f(S_{us})$$

45. berechnet werden, wobei $f(S_{us})$ eine Funktion repräsentiert, deren Wert monoton fällt, wenn der Wert des Unschärtemaskensignals S_{us} ansteigt.

2. Verfahren gemäß Anspruch 1, wobei das Originalbild ein Strahlungsbild ist.

50. 3. Verfahren gemäß Anspruch 2, wobei das Strahlungsbild auf einem stimulierbaren Phosphorblatt gespeichert wurde.

55. 4. Verfahren gemäß Anspruch 3, wobei ein Bildsignal, welches das Strahlungsbild repräsentiert und als Originalbildsignal S_{org} dient, detektiert wird, indem das stimulierbare Phosphorblatt mit stimulierender Strahlung, welche das stimulierbare Phosphorblatt anregt, Licht anteilmäßig zu der auf dem stimulierbaren Phosphorblatt während seiner Bestrahlung gespeicherten Energiemenge zu emittieren, bestrahlt wird und das emittierte Licht fotoelektrisch nachgewiesen wird.

5. Verfahren gemäß Anspruch 4, wobei die stimulierende Strahlung ein Laserstrahl ist.
6. Verfahren gemäß Anspruch 1, wobei das Originalbild ein Röntgenbild ist, das auf einem fotografischen Film aufgezeichnet wurde.
- 5 7. Verfahren gemäß Anspruch 1, worin die Ableitung der Funktion $f(S_{us})$ stetig ist.
8. Verfahren gemäß Anspruch 7, wobei das Originalbild ein Strahlungsbild ist.
- 10 9. Verfahren gemäß Anspruch 8, wobei das Strahlungsbild auf einem stimulierbaren Phosphorblatt gespeichert wurde.
- 15 10. Verfahren gemäß Anspruch 9, wobei ein Bildsignal, welches das Strahlungsbild repräsentiert und als Originalbildsignal S_{org} dient, detektiert wird, indem das stimulierbare Phosphorblatt mit stimulierender Strahlung, welche das stimulierbare Phosphorblatt anregt, Licht anteilmäßig zu der auf dem stimulierbaren Phosphorblatt während seiner Bestrahlung gespeicherten Energiemenge zu emittieren, bestrahlt wird und das emittierte Licht fotoelektrisch nachgewiesen wird.
- 20 11. Verfahren gemäß Anspruch 10, wobei die stimulierende Strahlung ein Laserstrahl ist.
12. Verfahren gemäß Anspruch 7, wobei das Originalbild ein Röntgenbild ist, das auf einem fotografischen Film aufgezeichnet wurde.

25 **Revendications**

1. Procédé pour comprimer une plage dynamique d'une image, selon lequel un signal d'image originale Sorg représentant une image originale est traité, et un signal d'image traité Sproc représentant une image présentant une plage dynamique plus étroite que l'image originale est ainsi générée,
30 le procédé de compression d'une plage dynamique d'une image comprenant les étapes de :
 - i) calcul de la valeur d'un signal de masque non net Sus correspondant à chacun d'éléments d'image dans ladite image originale en calculant la moyenne des valeurs de composantes de signal d'image dudit signal d'image originale Sorg, lesquelles composantes de signal d'image représentent les éléments d'image qui appartiennent à une région prédéterminée qui entoure chaque dit élément d'image,
35 caractérisé par :
 - ii) le calcul des valeurs dudit signal d'image traité Sproc à l'aide de la formule :

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$$Sproc = Sorg + f(Sus)$$

où $f(Sus)$ représente une fonction dont la valeur décroît de façon monotone lorsque la valeur dudit signal de masque non net Sus croît.

- 45 2. Procédé selon la revendication 1, dans lequel ladite image originale est une image de rayonnement.
3. Procédé selon la revendication 2, dans lequel ladite image de rayonnement a été stockée sur une feuille de phosphore stimulable.
- 50 4. Procédé selon la revendication 3, dans lequel un signal d'image, qui représente ladite image de rayonnement et qui joue le rôle dudit signal d'image originale Sorg, est détecté en exposant ladite feuille de phosphore stimulable à des rayons stimulable émettant de la lumière en proportion de la quantité d'énergie stockée dessus pendant son exposition à un rayonnement, et en détectant photoélectriquement la lumière émise.
- 55 5. Procédé selon la revendication 4, dans lequel lesdits rayons de stimulation sont un faisceau laser.
6. Procédé selon la revendication 1, dans lequel ladite image originale est une image rayons X qui a été enregistrée sur un film photographique.

7. Procédé selon la revendication 1, dans lequel la dérivée de la fonction $f(Su)$ est continue.
8. Procédé selon la revendication 7, dans lequel ladite image originale est une image de rayonnement.
- 5 9. Procédé selon la revendication 8, dans lequel ladite image de rayonnement a été stockée sur une feuille de phosphore stimulable.
- 10 10. Procédé selon la revendication 9, dans lequel un signal d'image qui représente ladite image de rayonnement et qui joue le rôle dudit signal d'image originale Sorg est détecté en exposant ladite feuille de phosphore stimulable à des rayons de stimulation qui ont pour effet que ladite feuille de phosphore stimulable émet de la lumière en proportion de la quantité d'énergie stockée dessus pendant son exposition à un rayonnement, et en détectant photoélectriquement la lumière émise.
- 15 11. Procédé selon la revendication 10, dans lequel lesdits rayons de stimulation sont un faisceau laser.
12. Procédé selon la revendication 7, dans lequel ladite image originale est une image rayons X qui a été enregistrée sur un film photographique.

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FIG.1

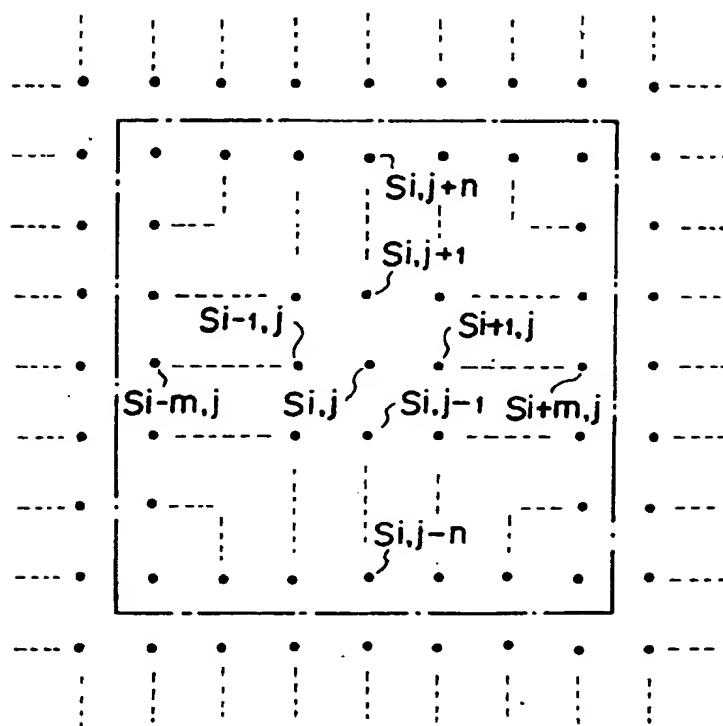


FIG.2

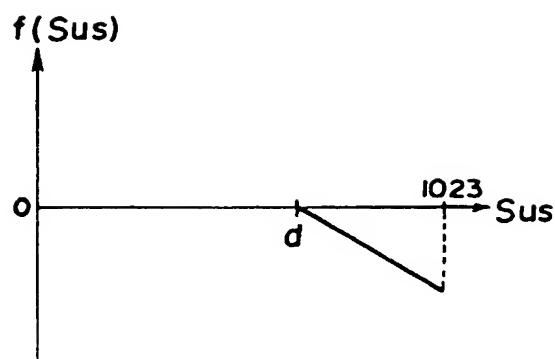


FIG.3

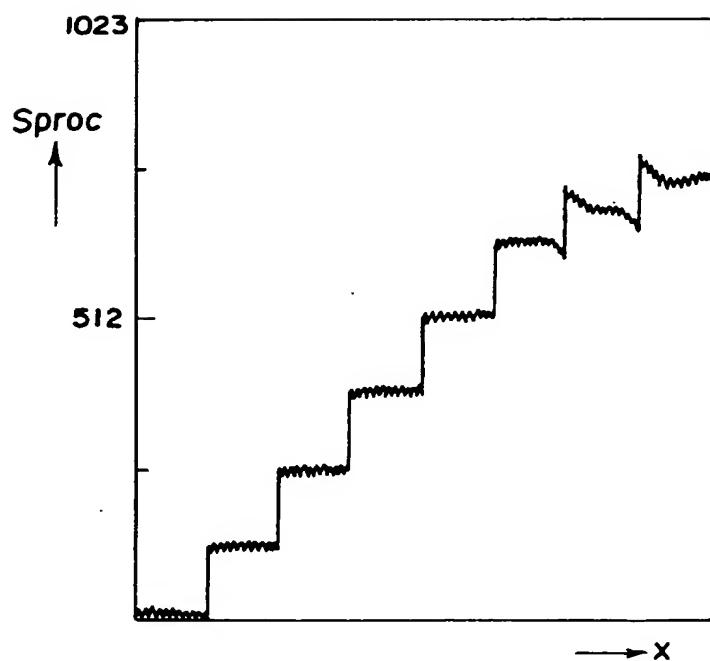


FIG. 4

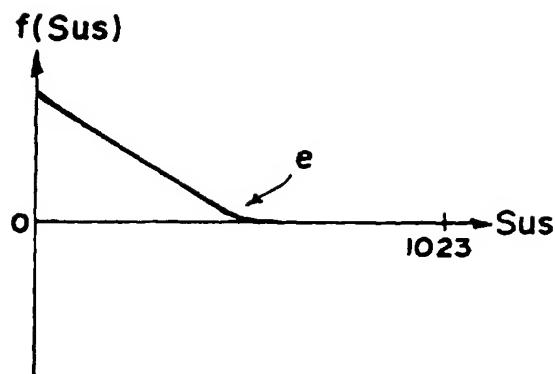
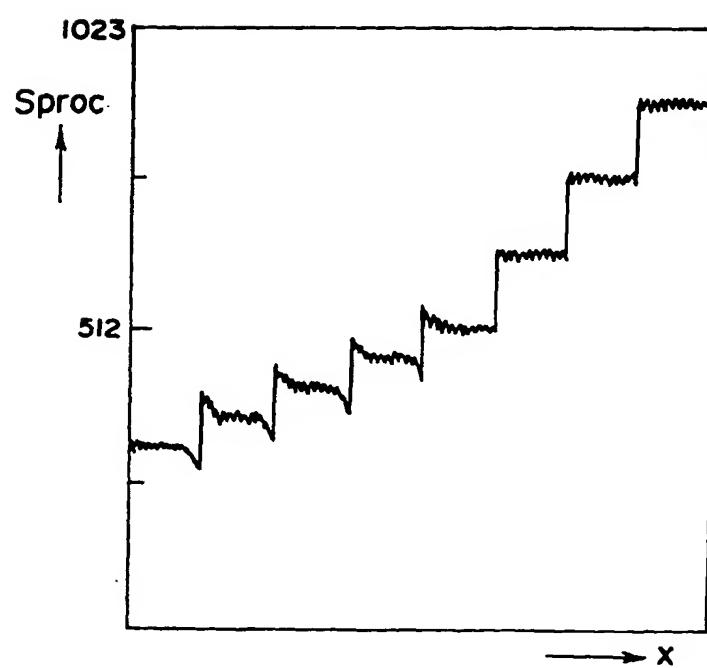
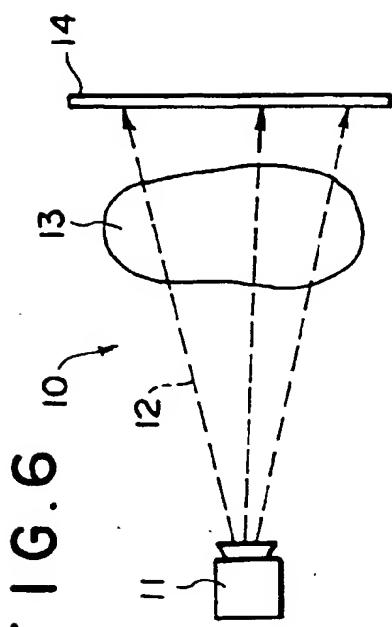
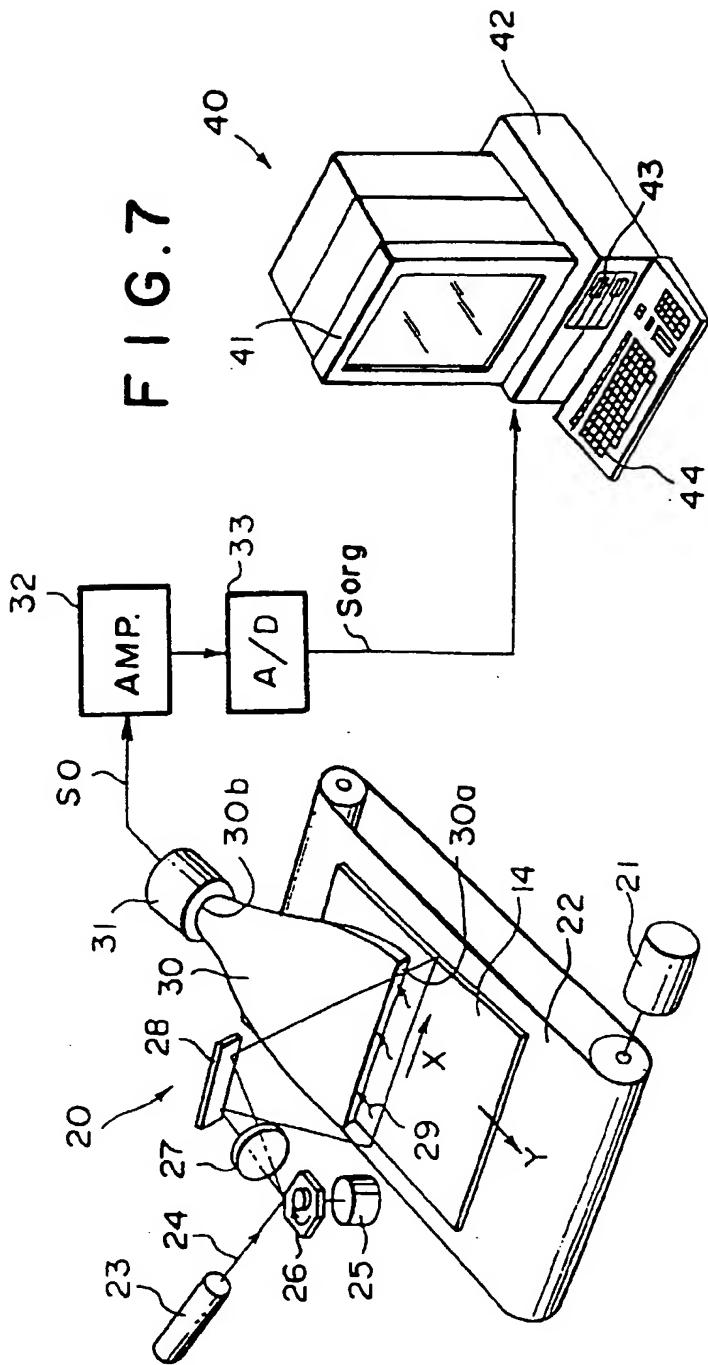
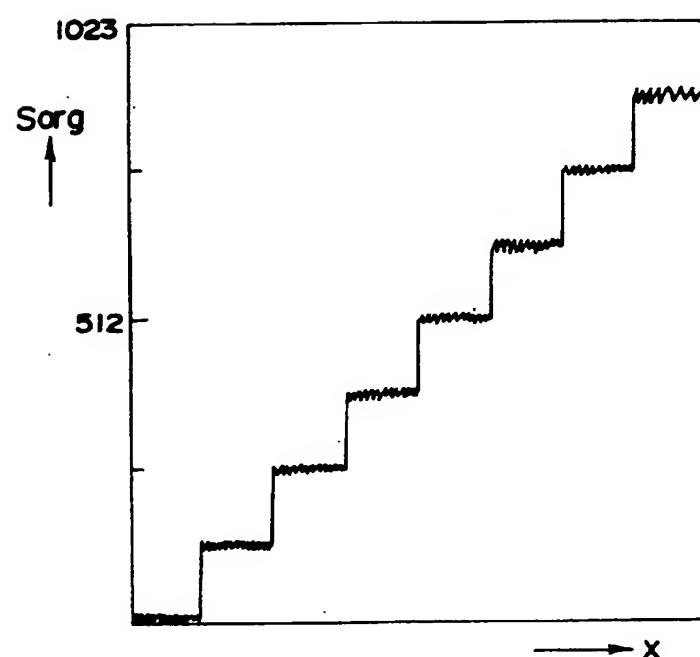


FIG. 5

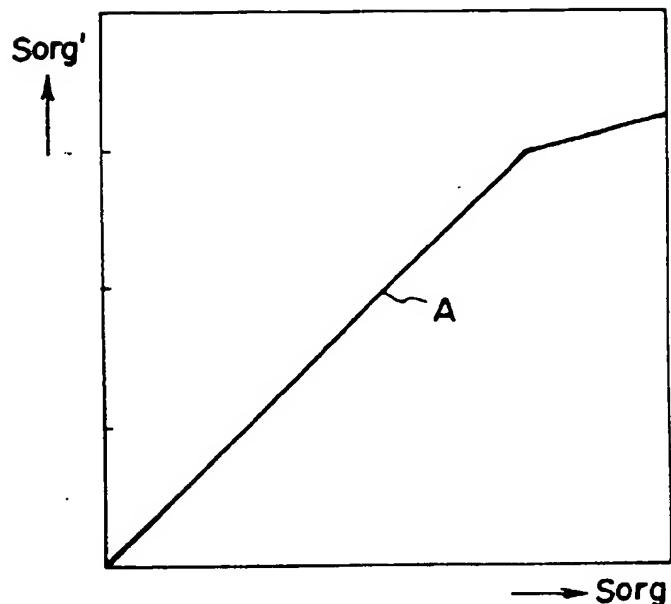


**FIG. 7**

F I G. 8



F I G. 9A
PRIOR ART



F I G. 9B
PRIOR ART

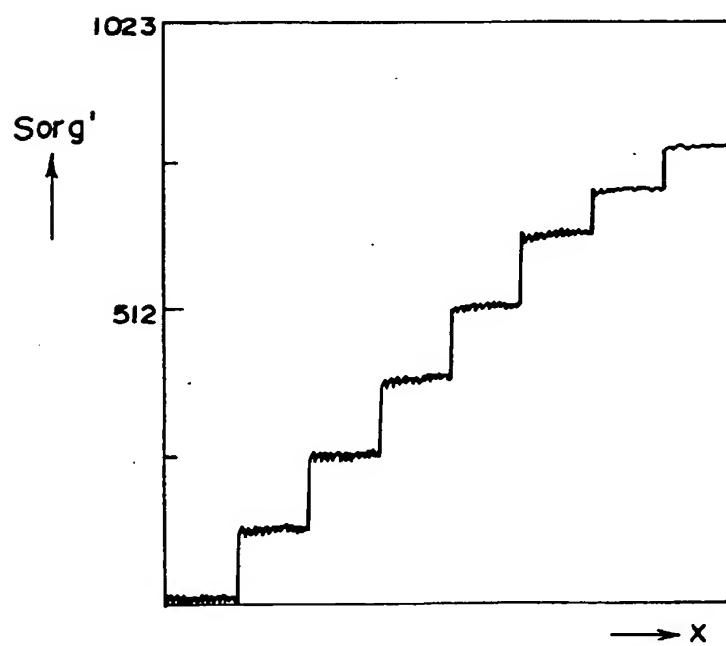


FIG.10A
PRIOR ART

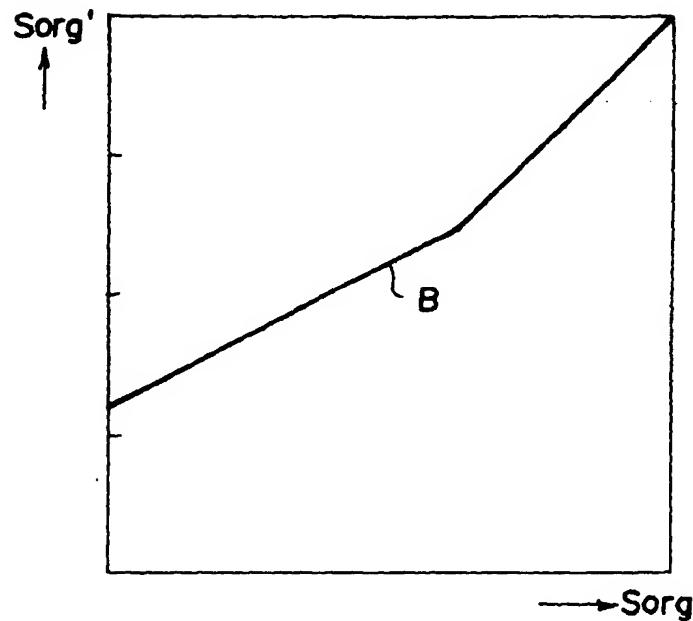


FIG.10B
PRIOR ART

